YAMCS

EIN OPEN SOURCE MISSION CONTROL SYSTEM FÜR DIE RAUMFAHRT

NICO MAAS

PI AND MORE 13

WER BIN ICH?

- Nico Maas
- Master of Science
- IT Systemelektroniker
- mail@nico-maas.de
- www.nico-maas.de
- Twitter: @nmaas87
- Mastodon: @nmaas87@chaos.social

AGENDA

- Anforderungen / Grundlagen / Implementierung
  - Das Ziel
  - Der Lander (Interfaces)
  - Unser Experiment (CCSDS)
  - Yamcs (MCS)
- Demo
- Ende

ANFORDERUNGEN / GRUNDLAGEN / IMPLEMENTIERUNG

DAS ZIEL

Wir beginnen mit einem Beispielsprojekt für einen nicht ganz hypothetischen Fall…


EIN STRAHLUNGSMESSER ZUM MOND?!

DER LANDER

Astrobotic Peregrine

Mission One

ULA Vulcan-Centaur

(2023-05-04)

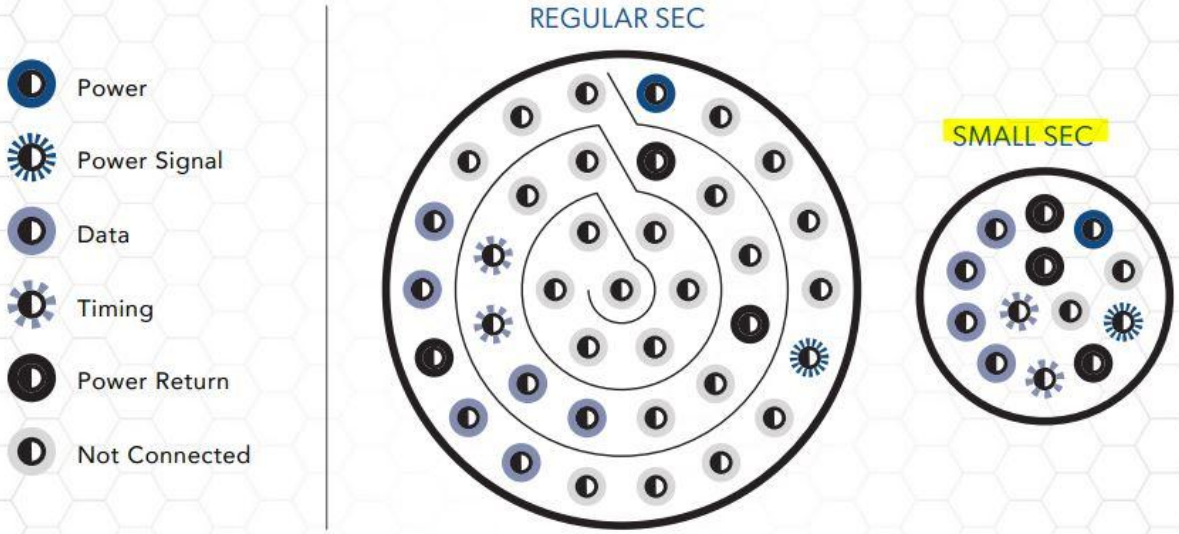
REQUIREMENTS?

- mechanische Interfaces
- elektrische Interfaces
- logische/Dateninterfaces
- Limits
  - Energie
  - Datendurchsatz

RTFM!

ELEKTRISCHE INTERFACES

Astrobotic provides power and data services through a Standard Electrical Connector (SEC). The SEC is a Glenair SuperNine connector of the MIL-DTL-38999 Series III screw type connector. The connector is available in a regular and small size, each with a standard pin configuration providing the contacts illustrated below. Please contact Astrobotic for the specific SEC part number for your payload.



POWER

Payloads are allocated two power circuits as a standard service. One is used for payload operations and if necessary, heater power. The other power circuit is used to perform deployments or actuations within the payload. The power provided is 28 ± 5% Vdc and the power circuits are current regulated, current-monitored, reverse-voltage protected, and over-voltage-protected.

DATA

Data circuits are available in either Serial RS-422 or SpaceWire configurations. Both data circuits support time at the tone, a time synchronization service that enables payloads to synchronize their internal clock with the lander and by extension UTC time. Payloads requiring the use of SpaceWire for additional data bandwidth must use the regular size SEC.

ELEKTRISCHE INTERFACES

- Small SEC connector
- Glenair Super Nine Buchse
- 28 V DC
- RS-422
- Time-at-the-tone

DATEN INTERFACES

Peregrine and Griffin use standard, well-defined data interfaces to simplify payload integration. Wired data services are provided through the SEC. Therefore, wired data services are available only while the payload is attached to the lander. Wireless data services are available to surface deployable payloads following separation from the lander. Orbit deployable payloads must establish an independent communication connection with Earth following separation from the lander.

NETWORK PROTOCOLS

Payloads may select between the three networking protocols to interface with the lander. Surface deployable payloads are recommended to select a wired data interface for communications prior to separation from the lander in addition to the wireless data interface.

- Serial RS-422, Serial Line IP (SLIP), and User Datagram Protocol (UDP)
- SpaceWire high-speed wired communication

NETWORK ARCHITECTURE

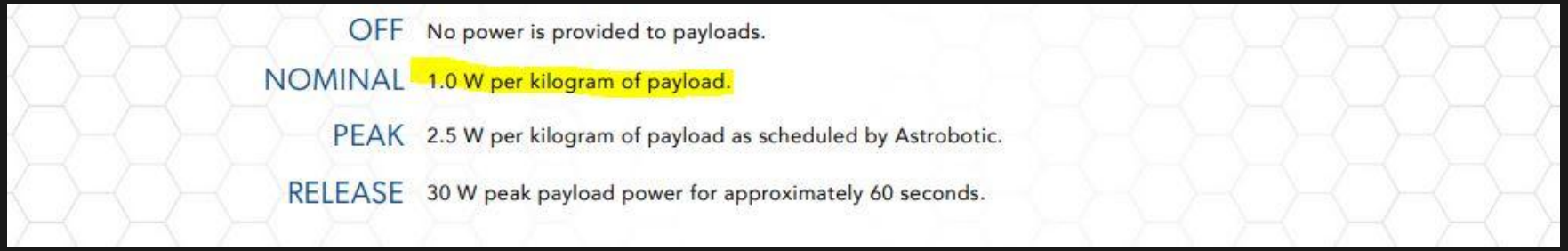
Payload telemetry and telecommands are transmitted from the lander to the Astrobotic Mission Control Center and then to the Payload Mission Control Centers without modification of payload data. Astrobotic contracts ground stations to communicate with the landers using X-Band for uplink and downlink. One-way latency in the connection between the customer and their payload on the Moon is nominally 4 seconds, although increases in latency may occur during some mission events.

DATEN INTERFACES

- Small SEC connector
  - RS-422
    - SLIP
      - IP
        - UDP
          - Nutzerdaten
- Time-at-the-tone
  - UDP Message
  - eigener Pin für “Tone”
- 4 Sekunden Latency (one way)

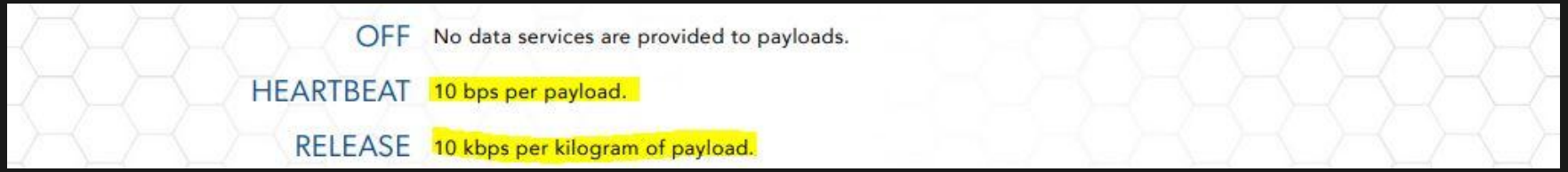
LIMITS

- Power



OFF	No power is provided to payloads.
NOMINAL	1.0 W per kilogram of payload.
PEAK	2.5 W per kilogram of payload as scheduled by Astrobotic.
RELEASE	30 W peak payload power for approximately 60 seconds.

- Daten



OFF	No data services are provided to payloads.
HEARTBEAT	10 bps per payload.
RELEASE	10 kbps per kilogram of payload.

LIMITS

- Power
  - 1 Watt / Kilogramm
- Daten
  - 10 bps (Cruise)
  - 10 kbps (Moon)

UNSER EXPERIMENT

CHECKLISTE

- Spannungsversorgung
  - 28 Volt Input? Ok!
- Datenformat
  - Daten / UDP / IP / SLIP / RS-422? Ok!
- Zeitsynchronisation
  - Time-at-the-tone Input? Ok!
- Limits
  - Power: < 1 Watt? Ok!
  - Daten Cruise: 10 bps? ~ x.x
  - Daten Moon: 10 kbps? ~ 9600 BAUD
- Effizientes “Raumfahrt Format” zum senden von Befehlen und empfangen von Messwerten?

NUTZLAST STEUERUNG

- Befehle zum Experiment -> Telecommands
- Datenempfang vom Experiment -> Telemetry

… im Kontext von multiplen Konzernen, Technologieträgern, Ausschreibungen, Projekten und Partnern

MISSION CONTROL SYSTEM ÜBERGREIFENDE ANFORDERUNGEN: STANDARDS?

CCSDS

Consultative Committee for Space Data Systems

“Der” Standard - egal welche Ausschreibung, egal welches Land - egal ob Datentypen, Formate, Kompression, …

CCSDS Approved Documents

- Blue: Recommended Standards
- Magenta: Recommended Practices
- Green: Informational Reports
- Orange: Experimental
- Yellow: Record
- Silver: Historical
- All Active Publications
- Recently Released Documents

Other

- Review Documents
- Reference Models
- Non-English Versions of Documents

Publications

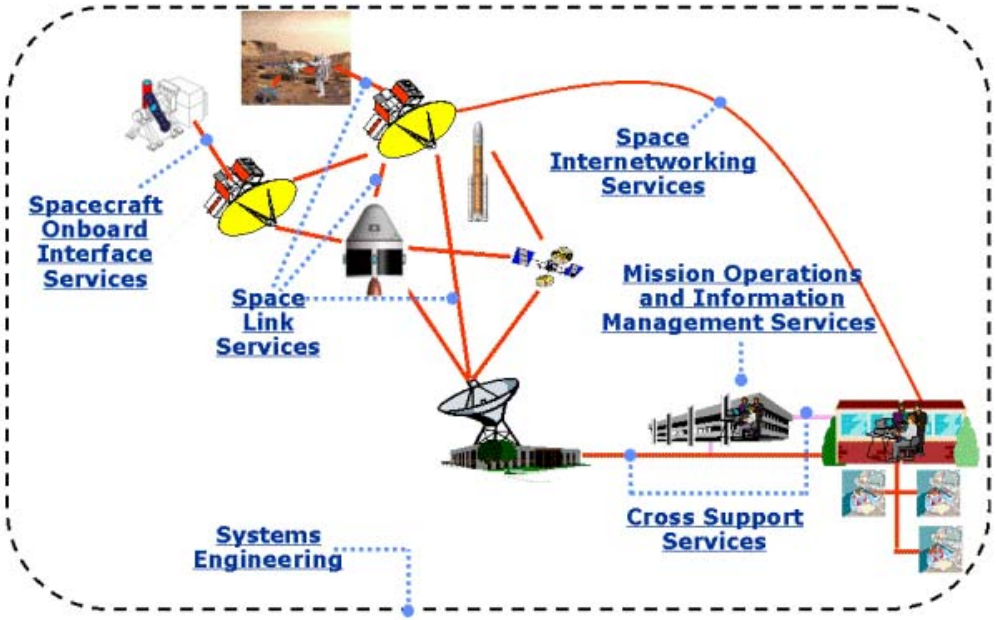
Locate CCSDS Documents by Book Color (see left), CCSDS Area (see below), or by using the Interactive Space Data System Reference Model (see below). To better understand the CCSDS Standards Development Process click here.

Documents by CCSDS Area:

- Space Internetworking Services
- Mission Ops. And Information Management Services
- Spacecraft Onboard Interface Services
- System Engineering
- Cross Support Services
- Space Link Services

Interactive Technical Area Reference Model:

Please click on a Technical Area link below to find the associated CCSDS Documents.



CCSDS 70 BLUE BOOKS

Currently 70 Books Listed

CCSDS 121.0-B-2 File size 403 KB	Working Group: SLS-MHDC	ISO Equivalent : 15887	Patent Licensing

Lossless Data Compression. **Blue Book. Issue 2. April 2012.**
This Recommended Standard defines a source-coding data-compression algorithm and specifies how data compressed using the algorithm are inserted into source packets for retrieval and decoding. Issue 2: - increases the allowed values of block length J from {8, 16} to {8, 16, 32, 64}; - increases the maximum allowed value of the reference sample interval r from 256 to 4096; - allows the use of a restricted set of code options - defines a new subfield of the Source Configuration Field of the optional Compression Identification packet; - adds guidance for selection of code option when two or more code options gave the same performance for a block; - updates nomenclature subsection; - clarifies some text; - adds a dedication to Warner Miller.

CCSDS 122.0-B-2 File size 866 KB	Working Group: SLS-MHDC	ISO Equivalent : 26868	

Image Data Compression. **Blue Book. Issue 2. September 2017.**
This Recommended Standard defines an image-data compression algorithm applicable to digital data from payload instruments and specifies means to control compression rate and how these compressed data shall be inserted into source packets for retrieval and decoding. The current issue adds modifications to support the Recommended Standard for Spectral Pre-Processing Transform for Multispectral and Hyperspectral Image Compression.

CCSDS 122.1-B-1 File size 816 KB	Working Group: SLS-MHDC		

Spectral Preprocessing Transform for Multispectral and Hyperspectral Image Compression. **Blue Book. Issue 1. September 2017.**
This Recommended Standard is an extension to CCSDS 122.0-B-2, Image Data Compression (Blue Book, Issue 2), defining a data compression algorithm that can be applied to digital three-dimensional image data from payload instruments, such as multispectral and hyperspectral imagers, and specifying the compressed data format.

CCSDS 123.0-B-2 File size 863 KB	Working Group: SLS-MHDC		

Low-Complexity Lossless and Near-Lossless Multispectral and Hyperspectral Image Compression. **Blue Book. Issue 2. February 2019.**
The Recommended Standard for multispectral and hyperspectral image compression specifies a data compression algorithm applied to digital three-dimensional image data from payload instruments, such as multispectral and hyperspectral imagers. Lossless and near-lossless methods are specified, along with a format for storing the compressed data.

CCSDS 133.0-B-2

Space Packet Protocol

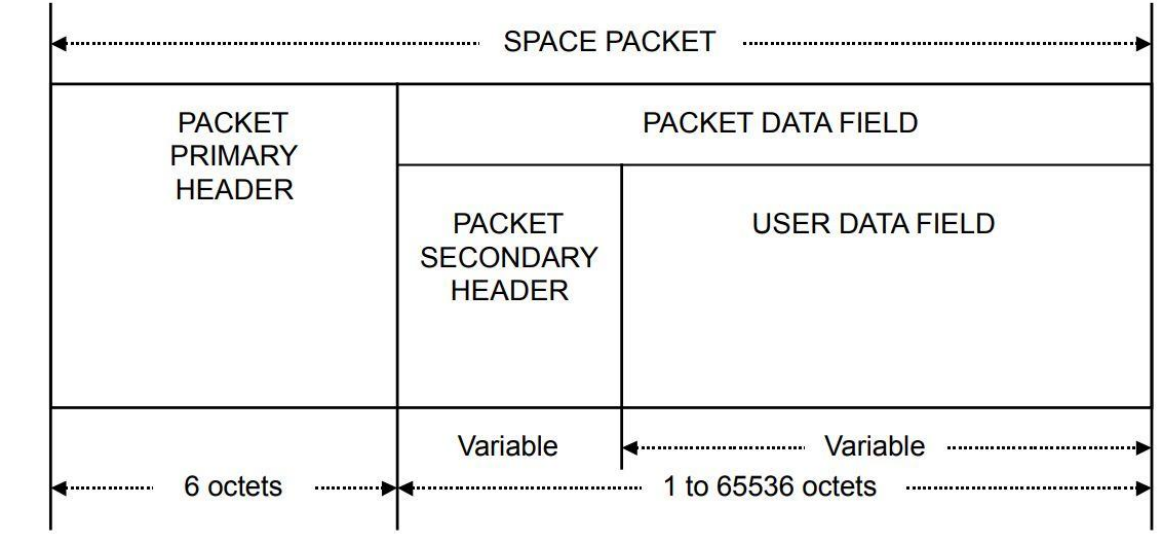


Figure 4-1: Space Packet Structural Components

sowie CRC-16 Checksumme nach User Data Field

AUFBAU 1/4: PRIMARY HEADER

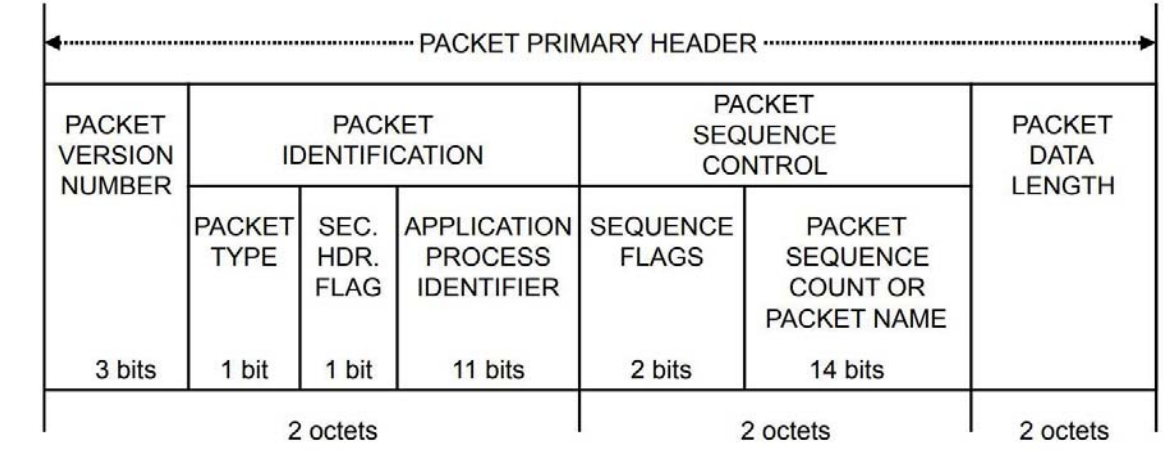


Figure 4-2: Packet Primary Header

AUFBAU 2/4: SECONDARY HEADER

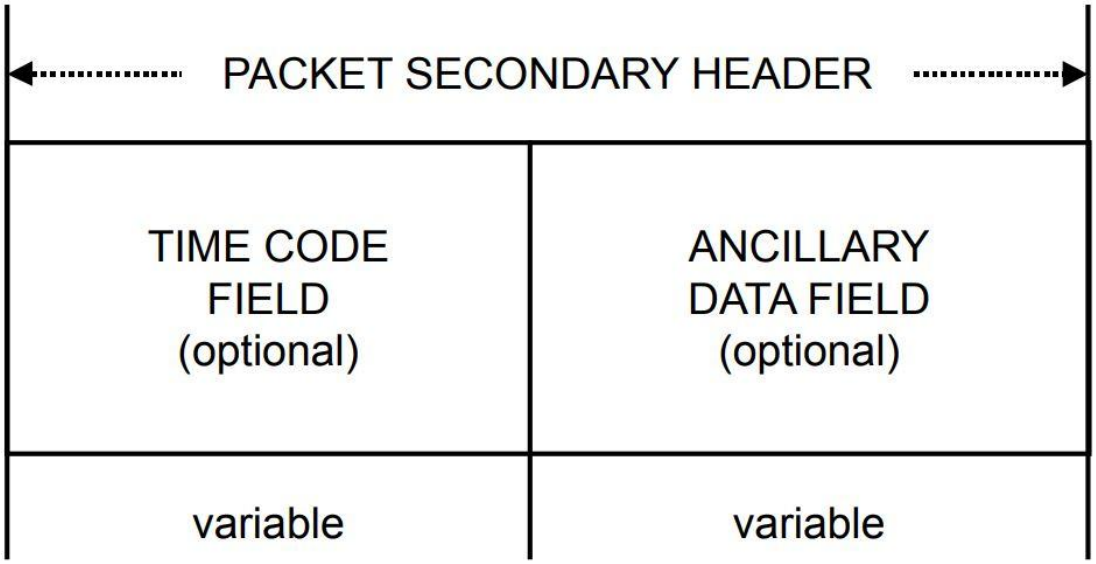


Figure 4-3: Packet Secondary Header

AUFBAU 3/4: USER DATA FIELD

- Was immer der Nutzer mag
- Empfehlung:
  - OpCode
  - Messwerte

AUFBAU 4/4: CRC FIELD

- Standard: CRC16-CCITT-FALSE

IMPLEMENTIERUNG

Telemetry

Part	Primary Header							Secondary Header				User Payload				CRC
Name	Packet Version Number	Packet Type	2nd Hdr Flag	Application Process Identifier (APID)	Seq Flag	Packet Counter	Packet Length	Service Type	Service Sub Type	Coarse Time	Fine Time	OpCode	Rad Dyn	Rad Sta	Rad Pulse	Cksum
bit	3	1	1	11	2	14	16	8	8	32	32	8	32	32	32	16
byte	6							10				13				2
	31 byte / 248 bit															

Telecommand

Part	Primary Header							Secondary Header				User Payload				CRC
Name	Packet Version Number	Packet Type	2nd Hdr Flag	Application Process Identifier (APID)	Seq Flag	Packet Counter	Packet Length	Service Type	Service Sub Type			OpCode				Cksum
bit	3	1	1	11	2	14	16	8	8			8				16
byte	6							2				1				2
	11 byte / 88 bit															

31 BYTES

- Komplettes Datenpaket mit präziser Zeit, Zustandscodes, Messwerten, Checksumme…
- oder “Welcome to the Pi And More 13 !” als ASCII Text

NUTZLAST FERTIG!

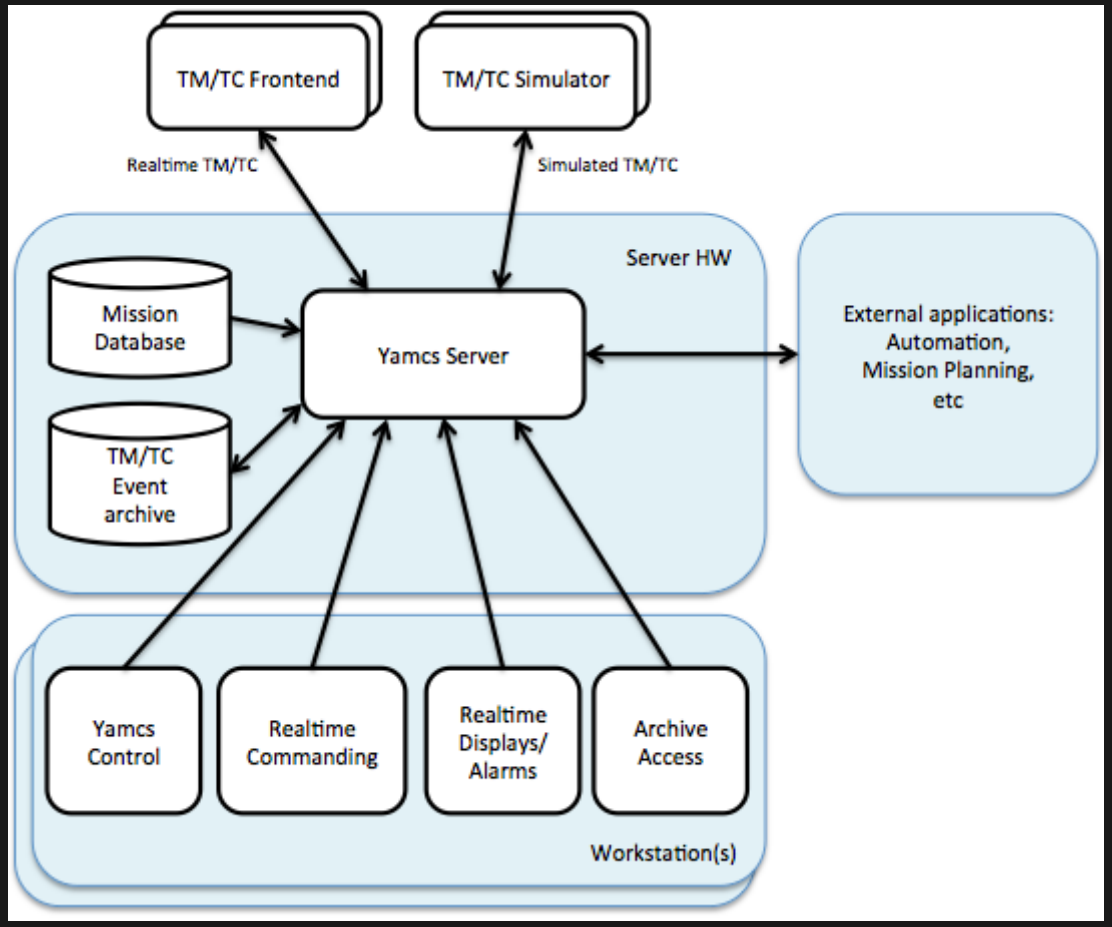
CCSDS Space Packet / UDP / IP / SLIP / RS-422

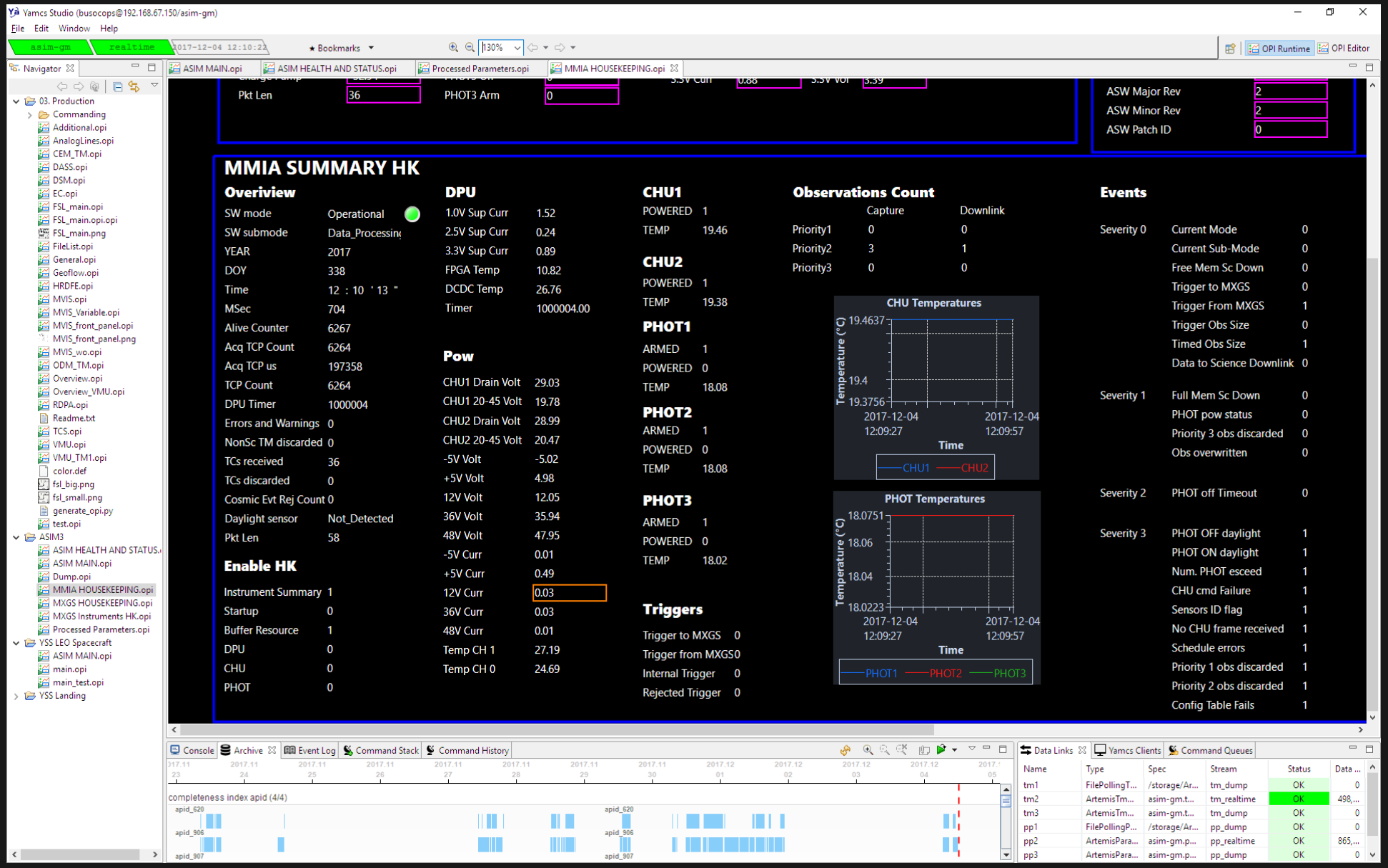
… UND WIE BEDIENT MAN DAS NUN?

- TM “übersetzen”:
  - Raw Value
  - Engineering / Calibrated Value
- Displays zur Darstellung / Kommandierung
- Events
- Alarme / Limits
- Datenarchive
- Export
- …

YAMCS

- früher: Yet Another Mission Control System
- Space Applications Services
- Open Source
- Mission Control System
- CCSDS kompatible
- https://www.yamcs.org/


TM/TC Frontend
TM/TC Simulator
Realtime TM/TC
Simulated TM/TC
Server HW
Mission Database
Yamcs Server
TM/TC Event archive
External applications: Automation, Mission Planning, etc
Yamcs Control
Realtime Commanding
Realtime Displays/ Alarms
Archive Access
Workstation(s)


Yamcs Studio (busocops@192.168.67.150/asim-gm)
File Edit Window Help
asim-gm realtime 2017-12-04 12:10:22
Bookmarks
130%
OPI Runtime
OPI Editor
Navigator
ASIM MAIN.opi
ASIM HEALTH AND STATUS.opi
Processed Parameters.opi
MMIA HOUSEKEEPING.opi
03. Production
Commanding
Additional.opi
AnalogLines.opi
CEM_TM.opi
DASS.opi
DSM.opi
EC.opi
FSL_main.opi
FSL_main.opi.opi
FSL_main.png
FileList.opi
General.opi
Geoflow.opi
HRDFE.opi
MVIS.opi
MVIS_Variable.opi
MVIS_front_panel.opi
MVIS_front_panel.png
MVIS_wo.opi
ODM_TM.opi
Overview.opi
Overview_VMU.opi
RDPA.opi
Readme.txt
TCS.opi
VMU.opi
VMU_TM1.opi
color.def
fsl_big.png
fsl_small.png
generate_opi.py
test.opi
ASIM3
ASIM HEALTH AND STATUS.
ASIM MAIN.opi
Dump.opi
MMIA HOUSEKEEPING.opi
MXGS HOUSEKEEPING.opi
MXGS Instruments HK.opi
Processed Parameters.opi
YSS LEO Spacecraft
ASIM MAIN.opi
main.opi
main_test.opi
YSS Landing
Pkt Len 36
PHOT3 Arm 0
ASW Major Rev 2
ASW Minor Rev 2
ASW Patch ID 0
MMIA SUMMARY HK
Overiview
SW mode Operational
SW submode Data_Processin
YEAR 2017
DOY 338
Time 12 : 10 ' 13 "
MSec 704
Alive Counter 6267
Acq TCP Count 6264
Acq TCP us 197358
TCP Count 6264
DPU Timer 1000004
Errors and Warnings 0
NonSc TM discarded 0
TCs received 36
TCs discarded 0
Cosmic Evt Rej Count 0
Daylight sensor Not_Detected
Pkt Len 58
Enable HK
Instrument Summary 1
Startup 0
Buffer Resource 1
DPU 0
CHU 0
PHOT 0
DPU
1.0V Sup Curr 1.52
2.5V Sup Curr 0.24
3.3V Sup Curr 0.89
FPGA Temp 10.82
DCDC Temp 26.76
Timer 1000004.00
Pow
CHU1 Drain Volt 29.03
CHU1 20-45 Volt 19.78
CHU2 Drain Volt 28.99
CHU2 20-45 Volt 20.47
-5V Volt -5.02
+5V Volt 4.98
12V Volt 12.05
36V Volt 35.94
48V Volt 47.95
-5V Curr 0.01
+5V Curr 0.49
12V Curr 0.03
36V Curr 0.03
48V Curr 0.01
Temp CH 1 27.19
Temp CH 0 24.69
CHU1
POWERED 1
TEMP 19.46
CHU2
POWERED 1
TEMP 19.38
PHOT1
ARMED 1
POWERED 0
TEMP 18.08
PHOT2
ARMED 1
POWERED 0
TEMP 18.08
PHOT3
ARMED 1
POWERED 0
TEMP 18.02
Triggers
Trigger to MXGS 0
Trigger from MXGS0
Internal Trigger 0
Rejected Trigger 0
Observations Count
Capture Downlink
Priority1 0 0
Priority2 3 1
Priority3 0 0
CHU Temperatures
Temperature (°C)
19.4637
19.4
19.3756
2017-12-04 12:09:27
2017-12-04 12:09:57
Time
CHU1 CHU2
PHOT Temperatures
Temperature (°C)
18.0751
18.06
18.04
18.0223
2017-12-04 12:09:27
2017-12-04 12:09:57
Time
PHOT1 PHOT2 PHOT3
Events
Severity 0
Current Mode 0
Current Sub-Mode 0
Free Mem Sc Down 0
Trigger to MXGS 0
Trigger From MXGS 1
Trigger Obs Size 0
Timed Obs Size 1
Data to Science Downlink 0
Severity 1
Full Mem Sc Down 0
PHOT pow status 0
Priority 3 obs discarded 0
Obs overwritten 0
Severity 2
PHOT off Timeout 0
Severity 3
PHOT OFF daylight 1
PHOT ON daylight 1
Num. PHOT esceed 1
CHU cmd Failure 1
Sensors ID flag 1
No CHU frame received 1
Schedule errors 1
Priority 1 obs discarded 1
Priority 2 obs discarded 1
Config Table Fails 1
Console
Archive
Event Log
Command Stack
Command History
completeness index apid (4/4)
apid_620
apid_906
apid_907
Data Links
Yamcs Clients
Command Queues
Name Type Spec Stream Status Data ...
tm1 FilePollingT... /storage/Ar... tm_dump OK 0
tm2 ArtemisTm... asim-gm.t... tm_realtime OK 498,...
tm3 ArtemisTm... asim-gm.t... tm_dump OK 0
pp1 FilePollingP... /storage/Ar... pp_dump OK 0
pp2 ArtemisPara... asim-gm.p... pp_realtime OK 865,...
pp3 ArtemisPara... asim-gm.p... pp_dump OK 0

WIE VERSTEHT/SPRICHT DAS MCS DIE BINÄREN CCSDS DATEN?

- Mission Database
- Beeinhaltet alle Elemente, Parameter, Positionen und wie diese zu interpretieren sind

MDB 1/4 - DATENTYPEN

	A	B	C	D	E	F	
	type name	eng type	raw type	encoding	eng unit	calibration	d
	float32	float	float	leee754_1985(32,LE)			
	uint1	uint	uint	1			
	uint2	uint	uint	2			
	uint3	uint	uint	3			
	uint4	uint	uint	4			
	uint8	uint	uint	8			
	uint11	uint	uint	11			
	uint14	uint	uint	14			
0	uint16	uint	uint	16			
1	uint32	uint	uint	32			
2	coarse-time	time	uint	32		gps_time_sec	
3	fine-time	time	uint	32		time_subsec	
4							

MDB 2/4 - PARAMETER

parameter name	data type
pktVer	uint3
pktType	uint1
secHdrFlag	uint1
APID	uint11
seqFlag	uint2
seqCount	uint14
pktLength	uint16
serviceType	uint8
serviceSubType	uint8
pktTimeCoarse	coarse-time
pktTimeFine	fine-time
OpCode	uint8
radDyn	float32
radSta	float32
radPul	uint32
crcSum	uint16

MDB 3/4 - TM PAKETE

Container name	parent	condition	flags	entry	position	s
ccsds_default						
				pktVer	0	
				pktType	0	
				secHdrFlag	0	
				APID	0	
				seqFlag	0	
				seqCount	0	
				pktLength	0	
				serviceType	0	
				serviceSubType	0	
				pktTimeCoarse	0	
				pktTimeFine	0	
radscience_packet	ccsds_default	APID==10815;serviceType==1;serviceSubType==2;				
				OpCode		
				radDyn	0	
				radSta	0	
				radPul	0	
				crcSum	0	
					0	

MDB 4/4 - TC PAKETE

A	B	C	D	E	F	G	H
command name	parent	argument assignment	flags	argument name	position	data type	default value
tc_packet_abstract			A				
				pktVer	0	FixedValue(3)	0
				pktType	0	FixedValue(1)	1
				secHdrFlag	0	FixedValue(1)	1
				APID	0	uint11	10815
				seqFlag	0	FixedValue(2)	3
				seqCount	0	uint14	1
				pktLength	0	uint16	4
				serviceType	0	uint8	1
				serviceSubType	0	uint8	2
tc_packet	tc_packet_abstract						
				OpCode	0	uint8	0
				crcSum	0	uint16	0
Mk3-P.ping	tc_packet	OpCode=1					
Mk3-P.getSensor	tc_packet	OpCode=10					
Mk3-P.sensorAutoOn	tc_packet	OpCode=11					
Mk3-P.sensorAutoOff	tc_packet	OpCode=12					
Mk3-P.ledOff	tc_packet	OpCode=20					
Mk3-P.ledOn	tc_packet	OpCode=21					
Mk3-P.ledHeartBeat	tc_packet	OpCode=22					
Mk3-P.ledTime	tc_packet	OpCode=23					
Mk3-P.syncTime	tc_packet	OpCode=30					

WIE KOMMEN DIE BINÄREN DATEN AUS/INS MCS? 1/2

- eigenes Plugin schreiben
- TM / eingehender Datenstrom
  - Telemetrie von Nutzlast annehmen
  - Entpacken
    - dekodiere Paket mit SLIP
    - lade und prüfe das darin verpackte IP Paket
    - lade und prüfe das darin verpackte UDP Paket
    - entnehmen CCSDS Paket aus UDP Payload
    - prüfe CRC16 Checksumme
    - entpacke Inhalt mittels MDB

WIE KOMMEN DIE BINÄREN DATEN AUS/INS MCS? 2/2

- eigenes Plugin schreiben
- TC / ausgehender Datenstrom
  - Verpacken
    - CCSDS TC generieren
    - Sequence Counter erhöhen
    - CRC16 Checksumme generieren
    - Packe CCSDS Paket in UDP Paket
    - Packe UDP Paket in IP Paket
    - IP Paket mit SLIP kodieren
    - SLIP kodiertes Paket zur Nutzlast senden
  - Telekommando an Nutzlast senden


APEX
APEX MK.II
DPS1 PYLD
DPS2 CHRG
PWR PYLD
SODS
SOE
LO
PWR CHRG
SM/PYLD
AUX
EGSE
WAN

DEMO

FRAGEN?

Danke für Ihre Aufmerksamkeit -

und viel Spaß auf der Pi And More 13 :)!

www.nico-maas.de